Decadal Variability and Predictability of the West African Monsoon and Downstream Atlantic Hurricane Activity

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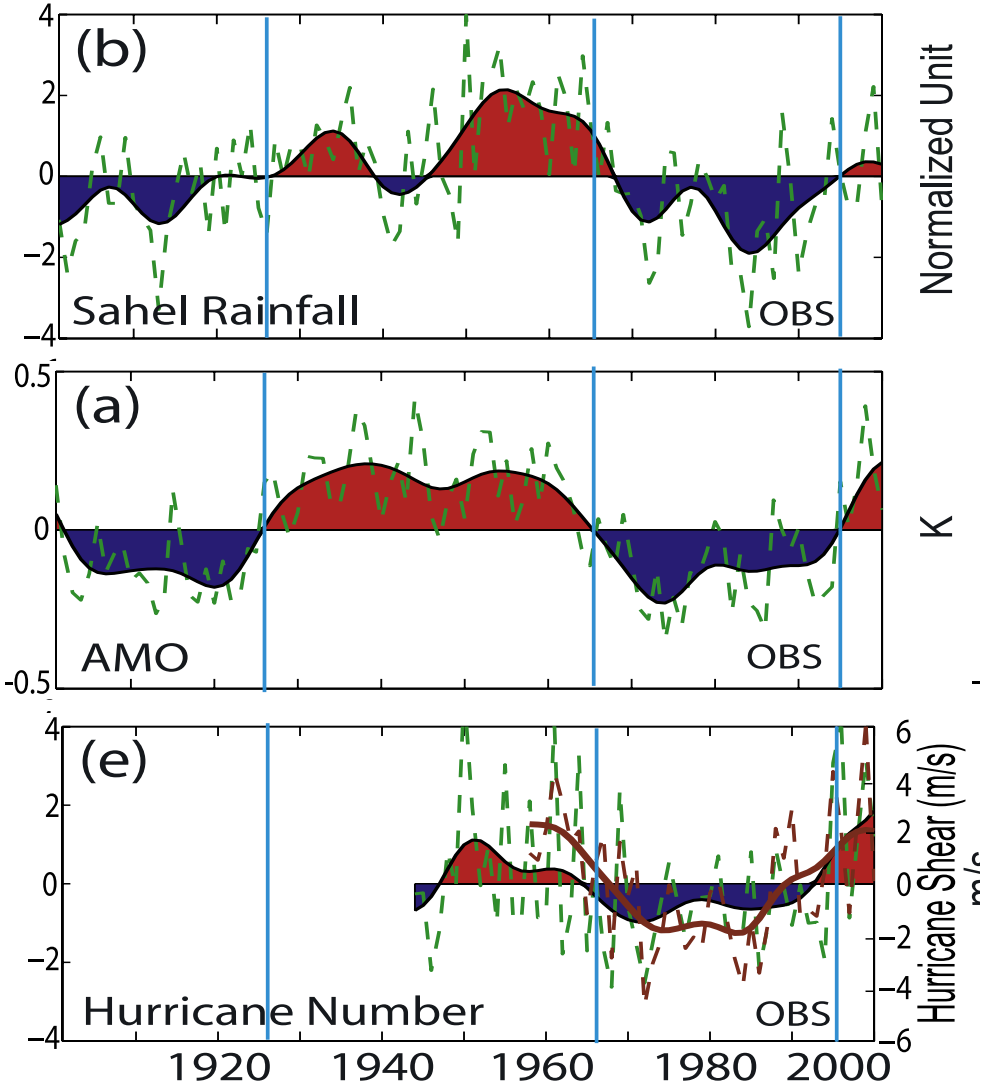
WAM, SST & Decadal Variability

Atlantic Multidecadal Oscillation

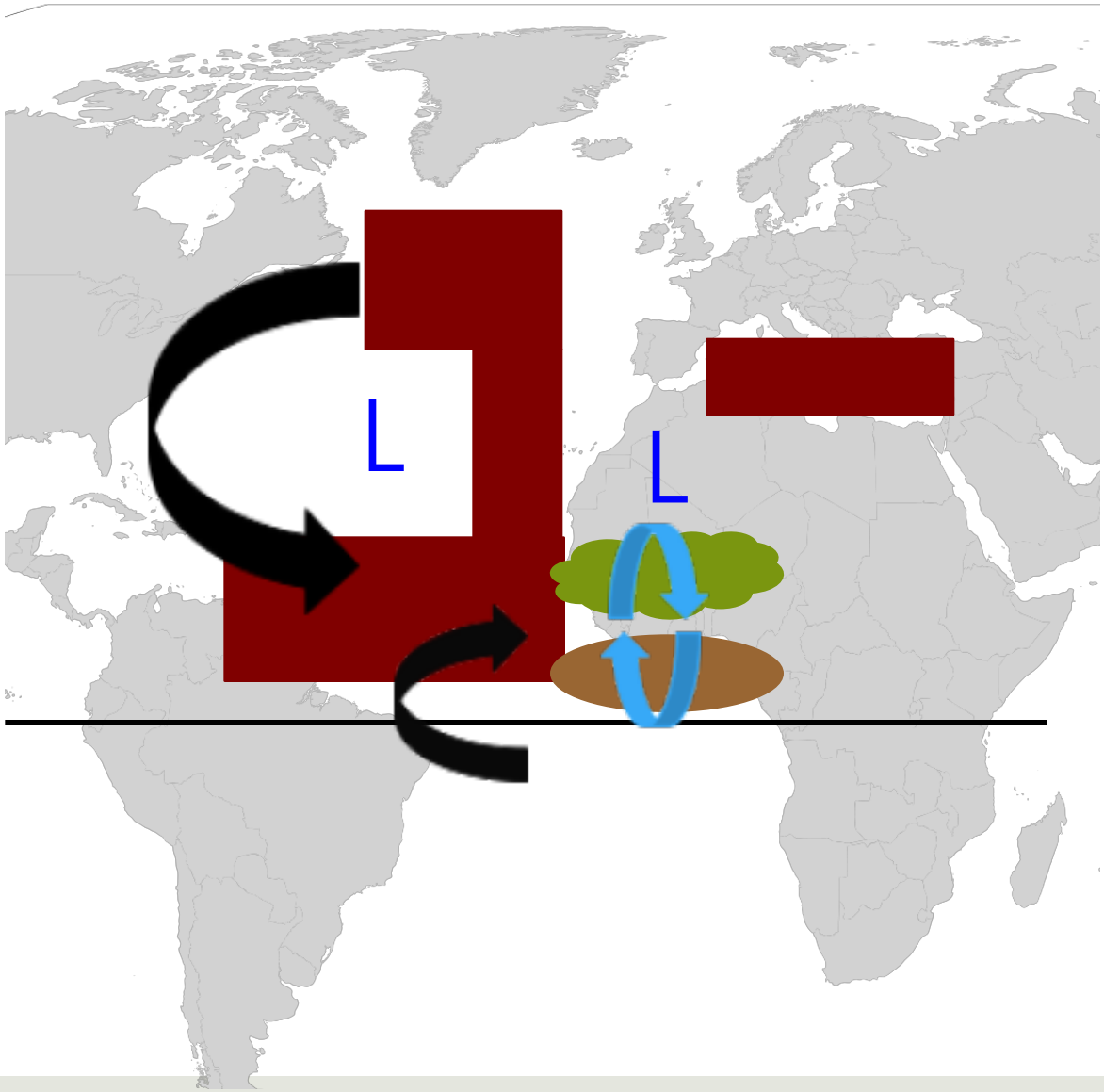


Zhang and Delworth 2006

Question 1

How does the AMO impact Sahel rainfall in observations?

In Warm AMO Phases:



Question 2

Do CMIP5 models capture the AMO – Sahel teleconnection and what processes are occurring/not occurring?

Decadal Variance

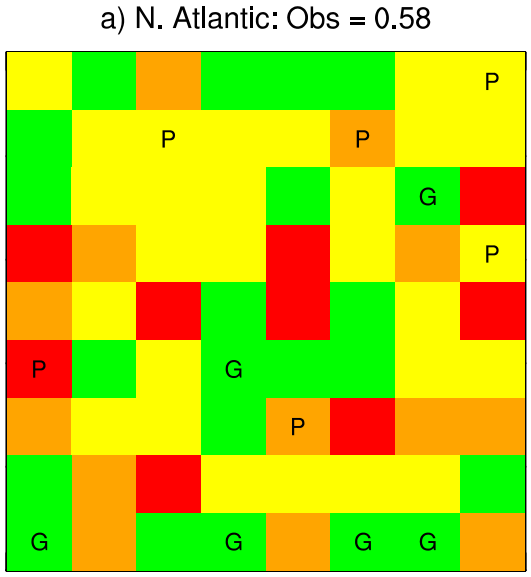
- CMIP5 historical simulations fail to capture the amount of decadal variance (>10 years) in Sahel rainfall and the AMO

	Observed	CMIP5 Hist. Mean
Sahel Rainfall	45 %	16 %
AMO	66 %	44 %

Sahel Rainfall – SST Decadal Correlation

- CMIP5 historical simulations simulate the correlation between between decadally filtered Sahel rainfall and SST in the North Atlantic

North Atlantic: r=0.58



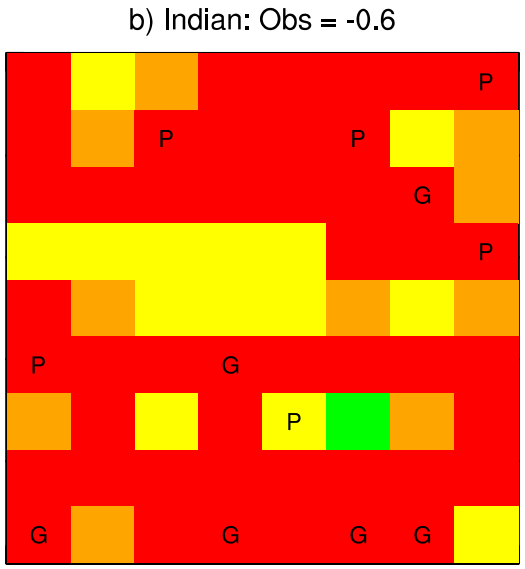
Color shows significance of correlation

GREEN > 90 %
YELLOW 70 – 90 %
ORANGE 50 – 70 %
RED < 50 % (e.g. opposite sign to observed)

Sahel Rainfall – SST Decadal Correlation

- The performance is even worse when considering the relationship with the Indian Ocean

Indian Ocean: r=-0.60



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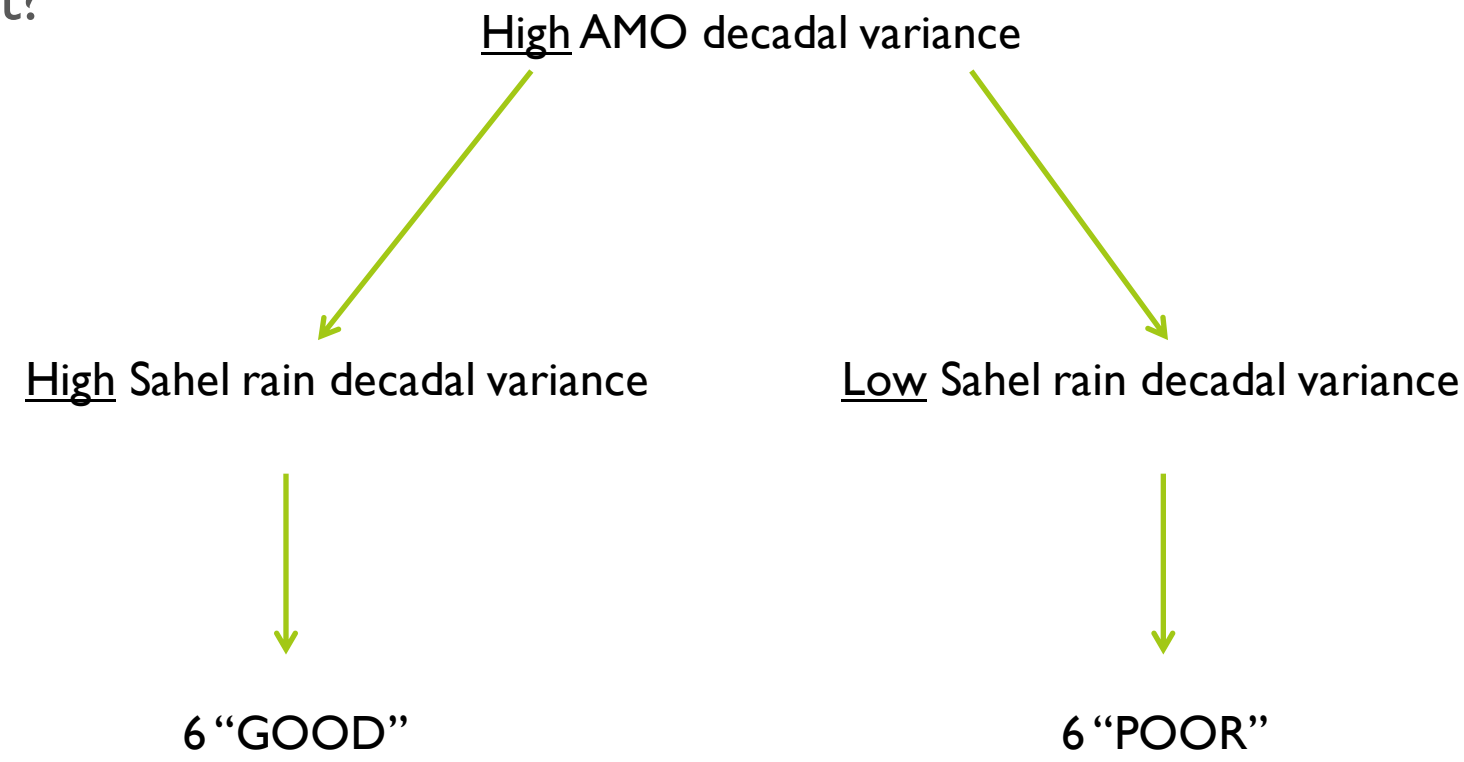
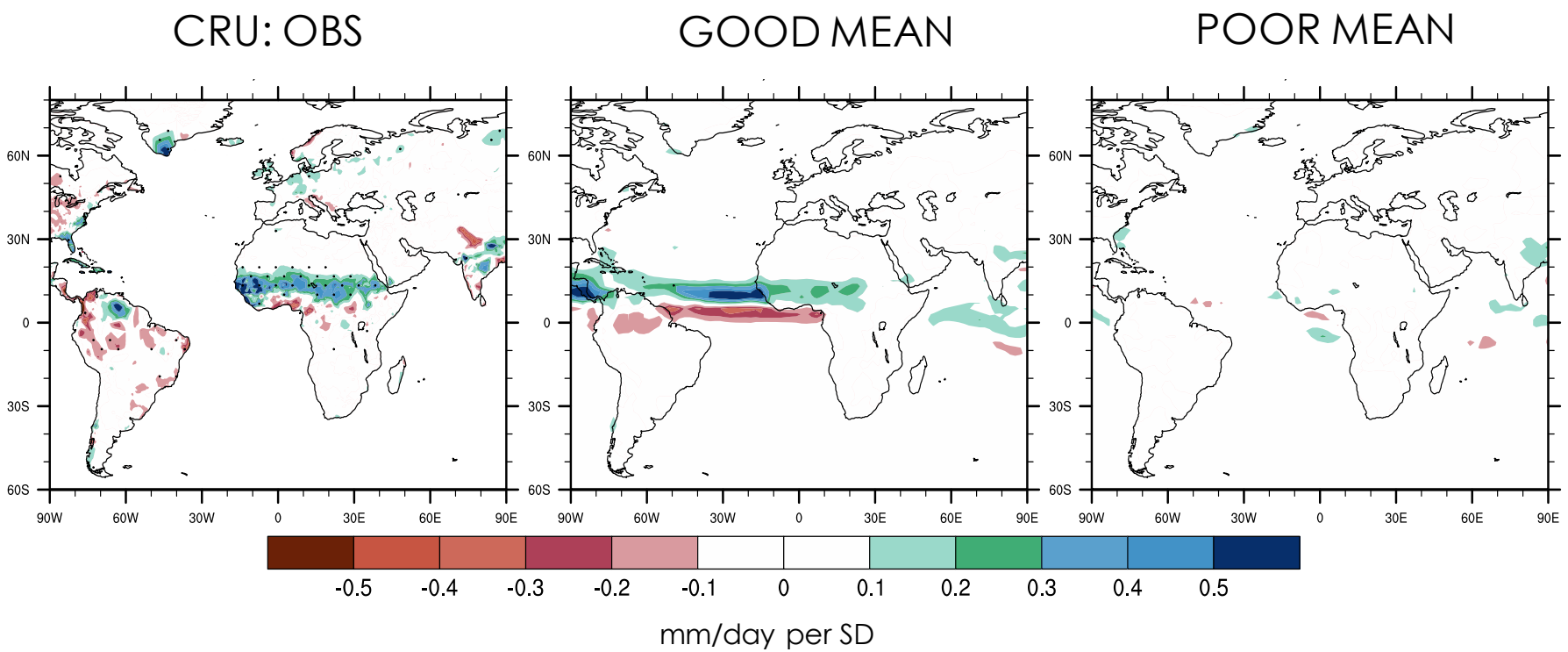
AMO – Sahel Rainfall

- Why do some models with high decadal variance in the AMO have high Sahel rainfall decadal variance, but others do not?

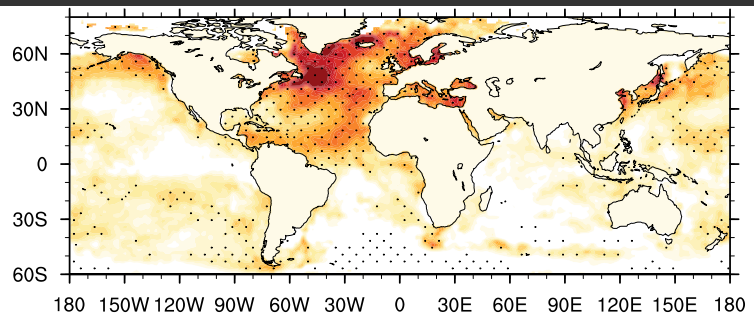


Rainfall Regressed onto AMO Index

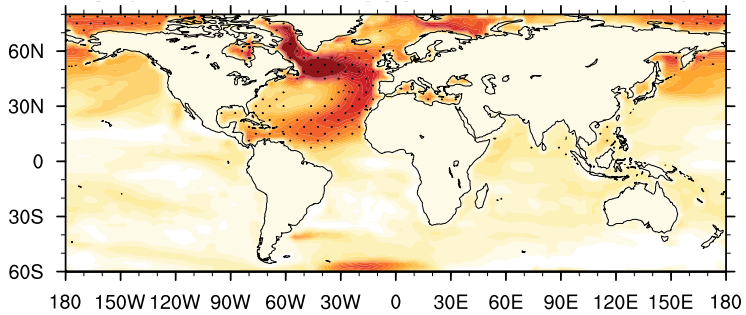


SST Regressed onto AMO Index

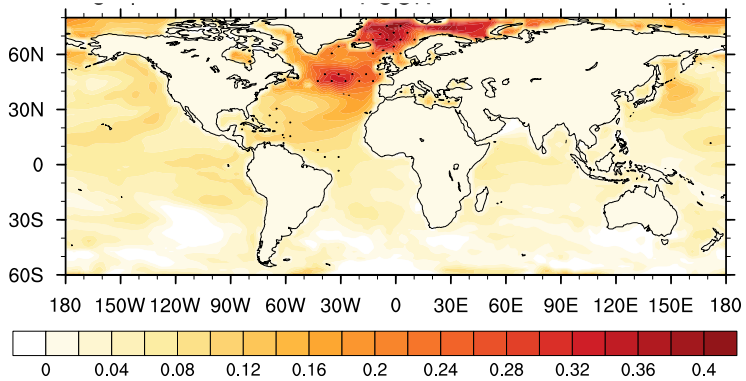
HadISST



GOOD MEAN



POOR MEAN



degC per SD

- The spatial pattern of the simulated AMO is highly important for the connection with Sahel rainfall

Why is the tropical signal of the AMO weak in poor models?

- **Clouds:**
  - Larger (more realistic) total cloud amount and variability in eastern basin of good models
  - Is total mean cloud amount related to simulation of SST variability?

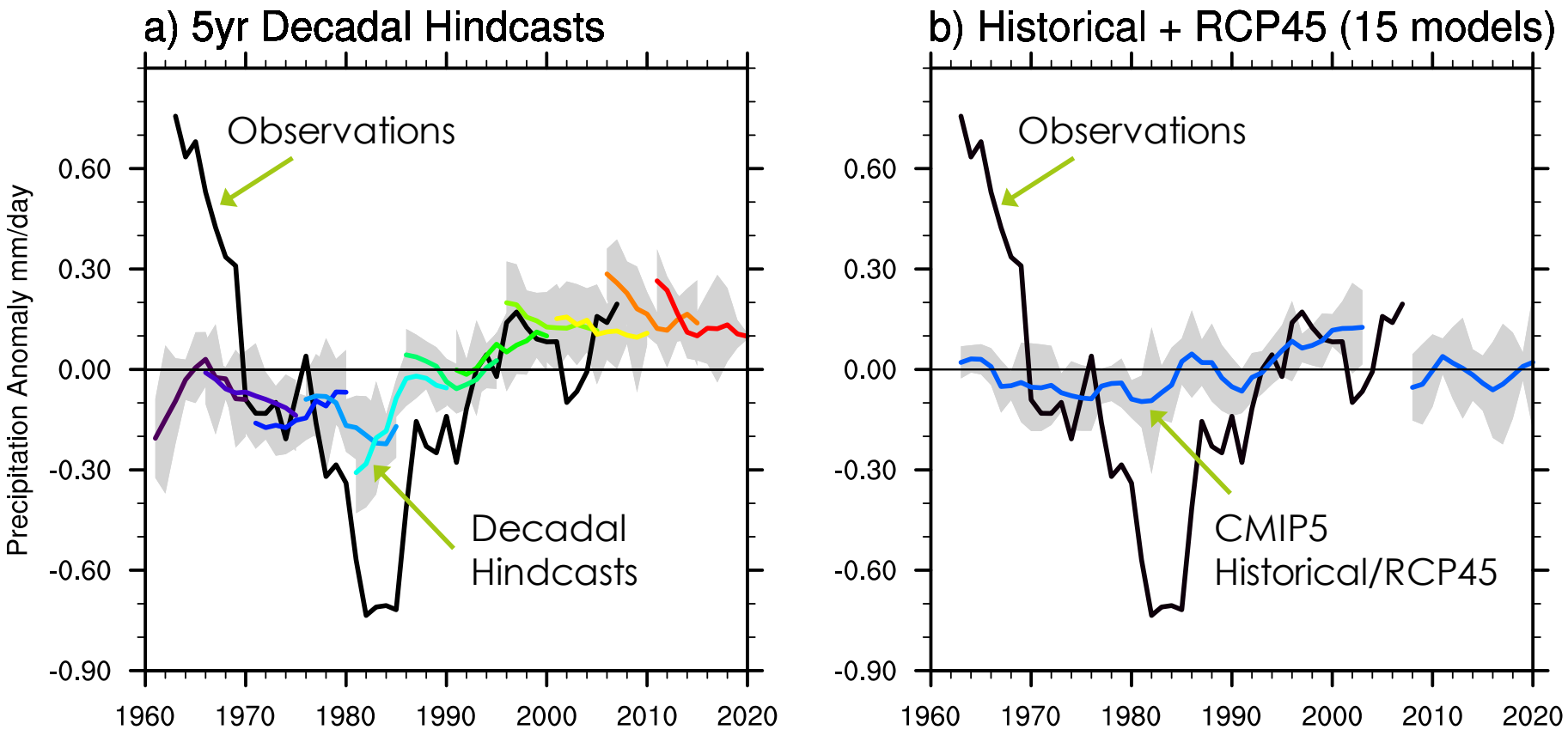
- **Dust:**
  - Good models decrease dust over N. Africa with increased SST, as expected
  - Poor models do not

- **Sulfate Aerosol Indirect Effect**
  - Require sulfates and clouds to be in same location for indirect effect to occur
  - This does not occur in poor models – primarily due to cloud distribution

Question 3

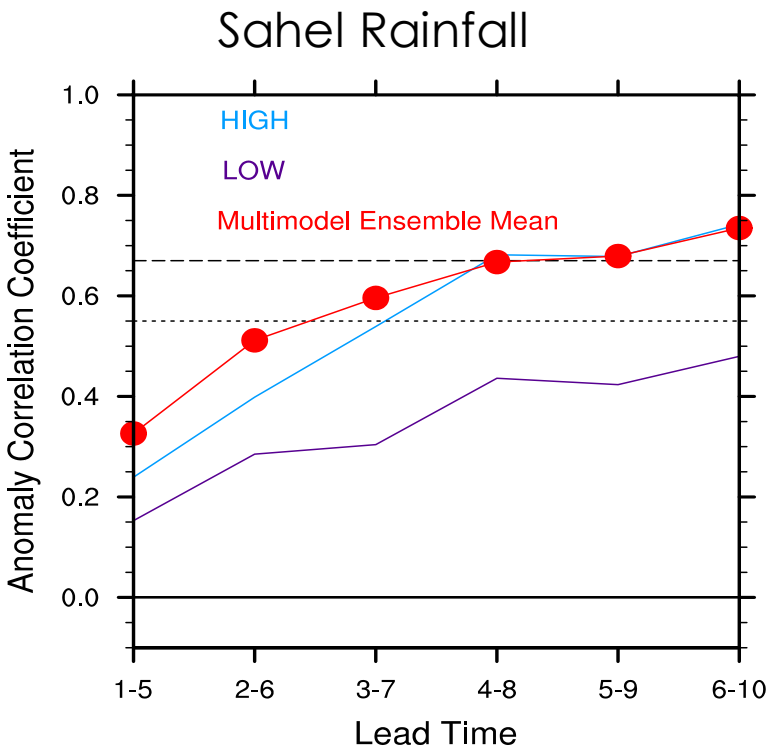
Can CMIP5 Decadal Hindcasts Predict Sahel Rainfall Variability?

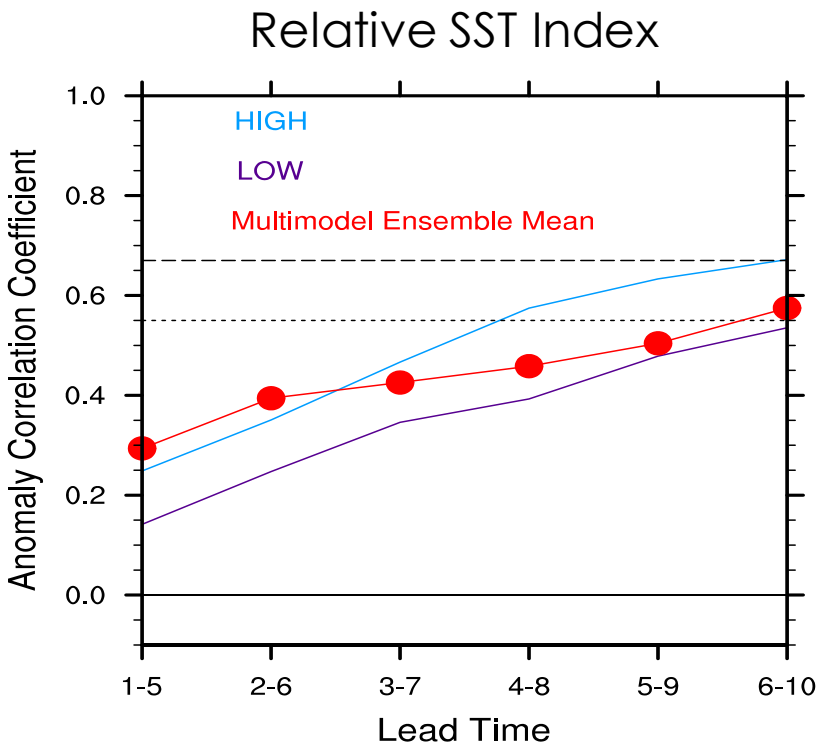
Sahel Rainfall



Grey shading: +/- one standard deviation

Understanding Improved Skill



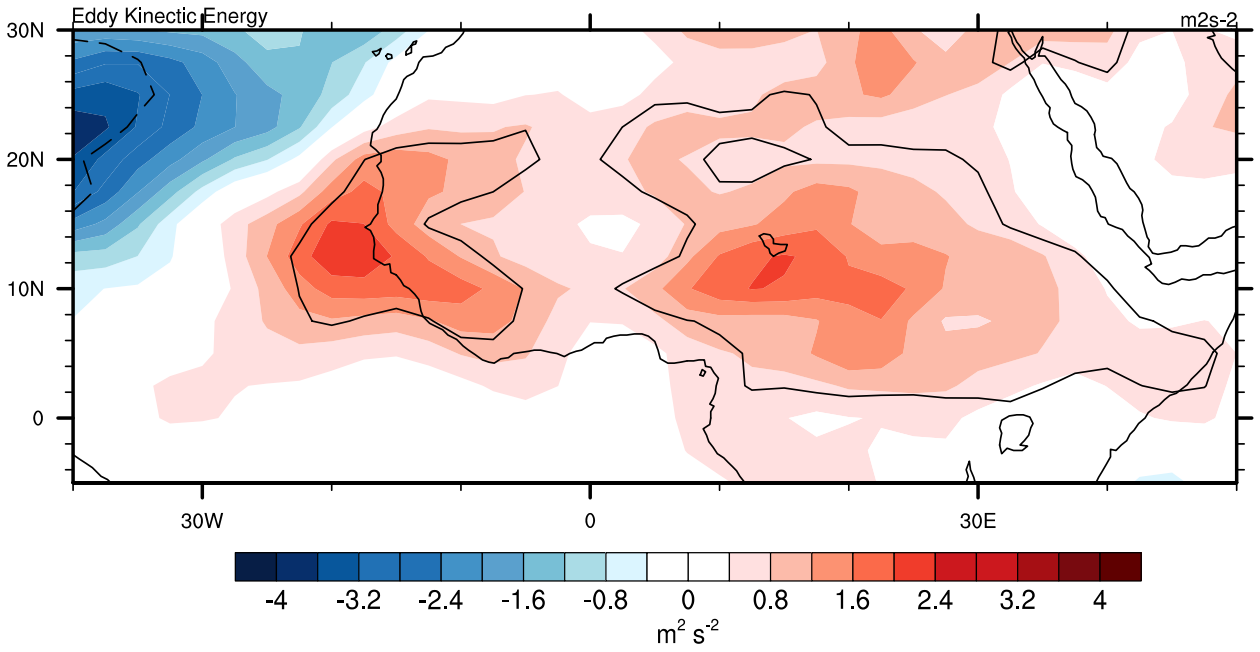


- A Relative SST index (RSI) is calculated following Giannini et al. (2013) as the annual mean subtropical North Atlantic SST minus the tropical mean (20°S-20°N) SST
- Models with a high RSI-Sahel rainfall correlation in historical simulations produce more skillful decadal hindcasts for both Sahel rainfall and the RSI

Question 4

What about the impact on Hurricanes?

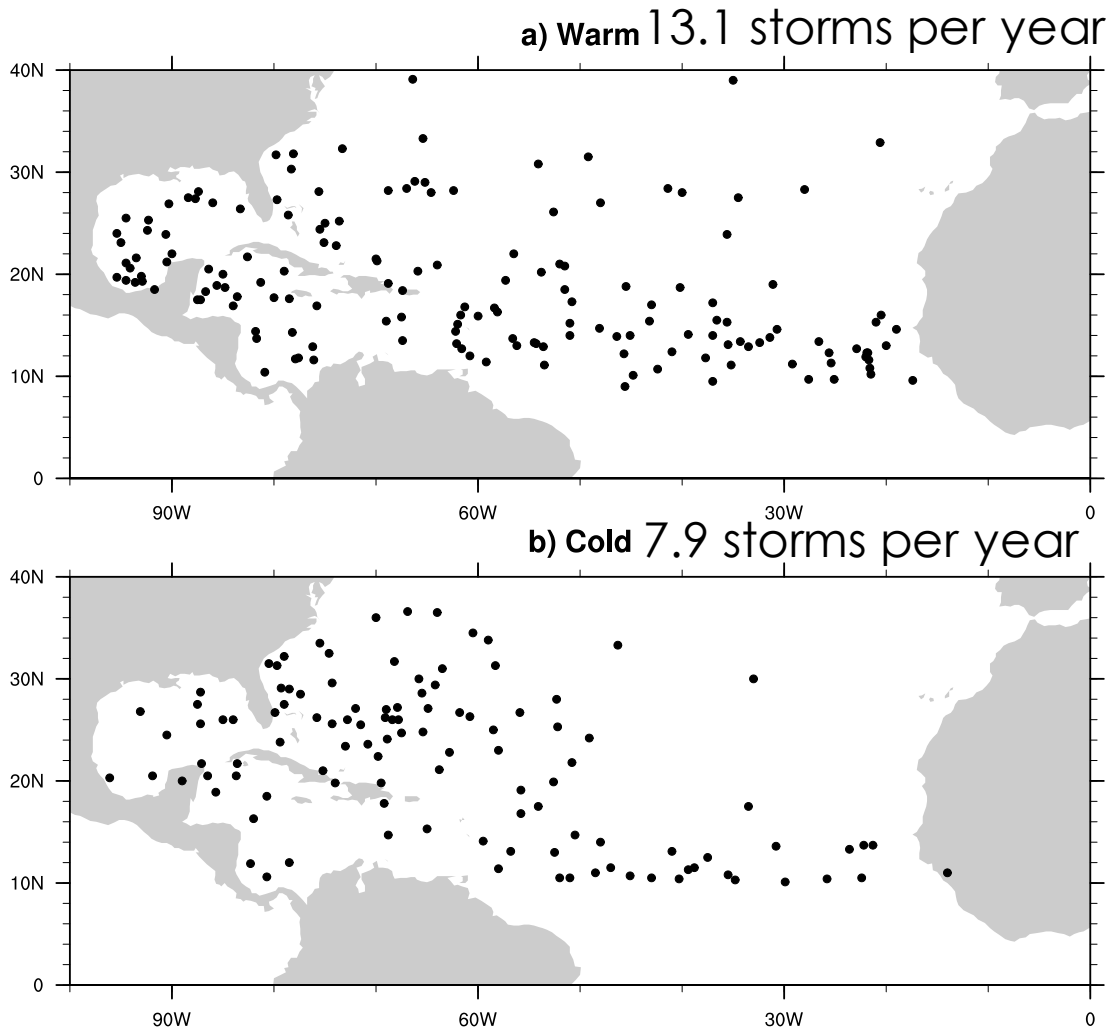
African Easterly Waves (AEWs)



Difference in Eddy Kinetic Energy (EKE) between warm and cold AMO phases

- AEWs vary decadally with the AMO

Tropical Cyclone Genesis



- No change in mean longitude but change in distribution

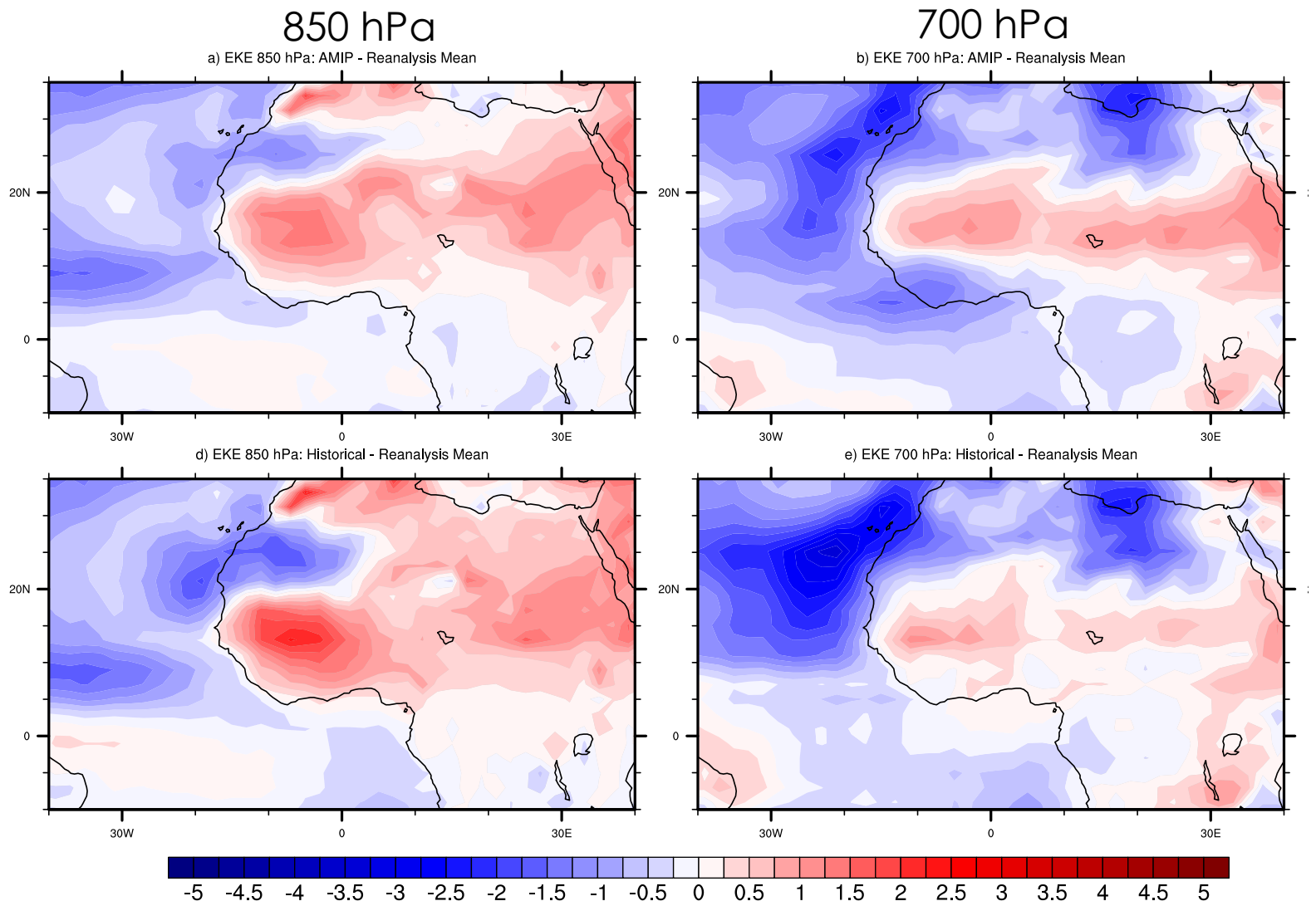
<u>Increased tropical cyclone frequency in warm AMO years</u>

→ Increased SST

→ Decreased vertical wind shear

→ *Increased AEWs*

AEWs in CMIP5?



Summary

- SST plays a large role in decadal predictability of Sahel rainfall BUT need to improve SST and atmospheric teleconnection to have a real impact on Sahel rainfall and potentially hurricane prediction
- CMIP5 models with well simulated AMO-Sahel teleconnections have a more realistic pattern of SSTs in the North Atlantic but SST errors could be due to errors with clouds, aerosol (sulfate and dust), ocean dynamics, vegetation?
- Decadal hindcasts of Sahel rainfall and the RSI have significant skill. Models that produce realistic correlations between the RSI and Sahel rainfall in historical simulations (not initialised with observations) have more skillful Sahel rainfall decadal hindcasts.
- Major errors in the simulation of AEWs in CMIP5 models → potentially large impacts on tropical cyclone simulation

More Detailed Information

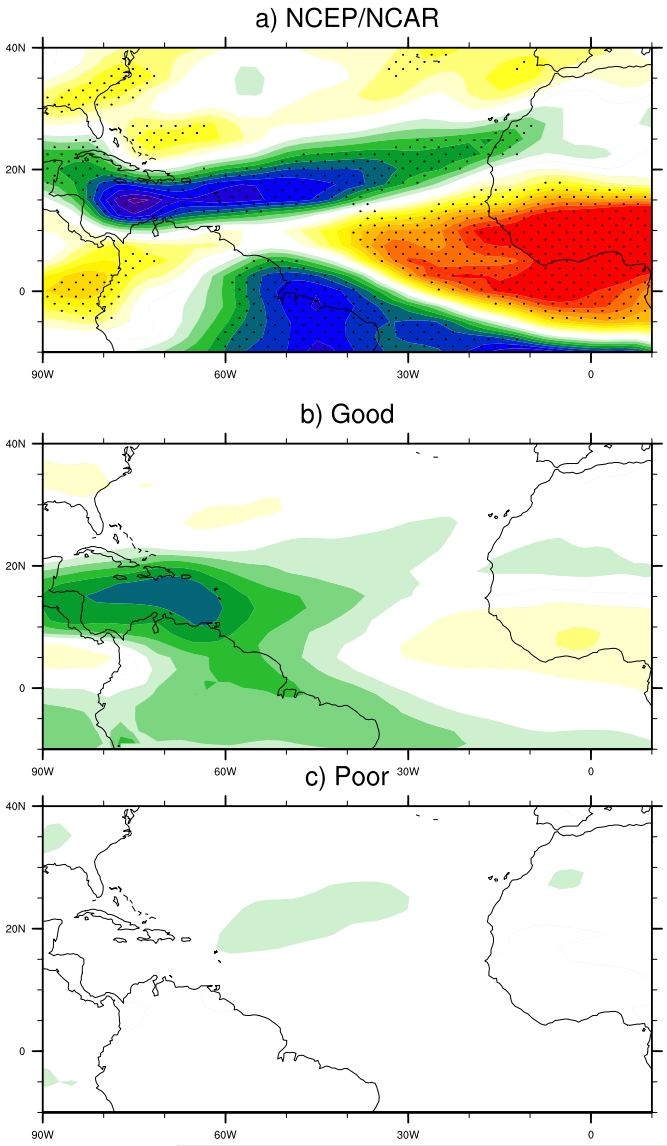
Martin, E. R., and C. Thorncroft 2014: **The impact of the AMO on the West African Monsoon Annual Cycle.** *Q. J. R. Meteorol. Soc.*, 140, 31-46 doi:10.1002/qj.2107.

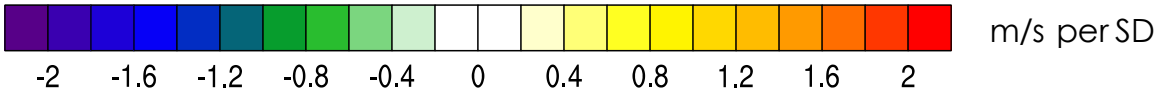
Martin, E. R., C. Thorncroft and B.B.B. Booth 2014: **The Multidecadal Atlantic SST - Sahel Rainfall Teleconnection in CMIP5 Simulations**. *J. Climate*, 27, 784-806 doi:10.1175/JCLI-D-13-00242.1.

Martin, E. R., and C. Thorncroft 2014: **Sahel Rainfall in Multimodel CMIP5 Decadal Hindcasts.** *Geophys. Res. Lett.*, 41, doi:10.1002/2014GL059338.

Martin, E. R., and C. Thorncroft 2015: **Representation of African Easterly Waves in CMIP5 models.** *J. Climate,* In Press.

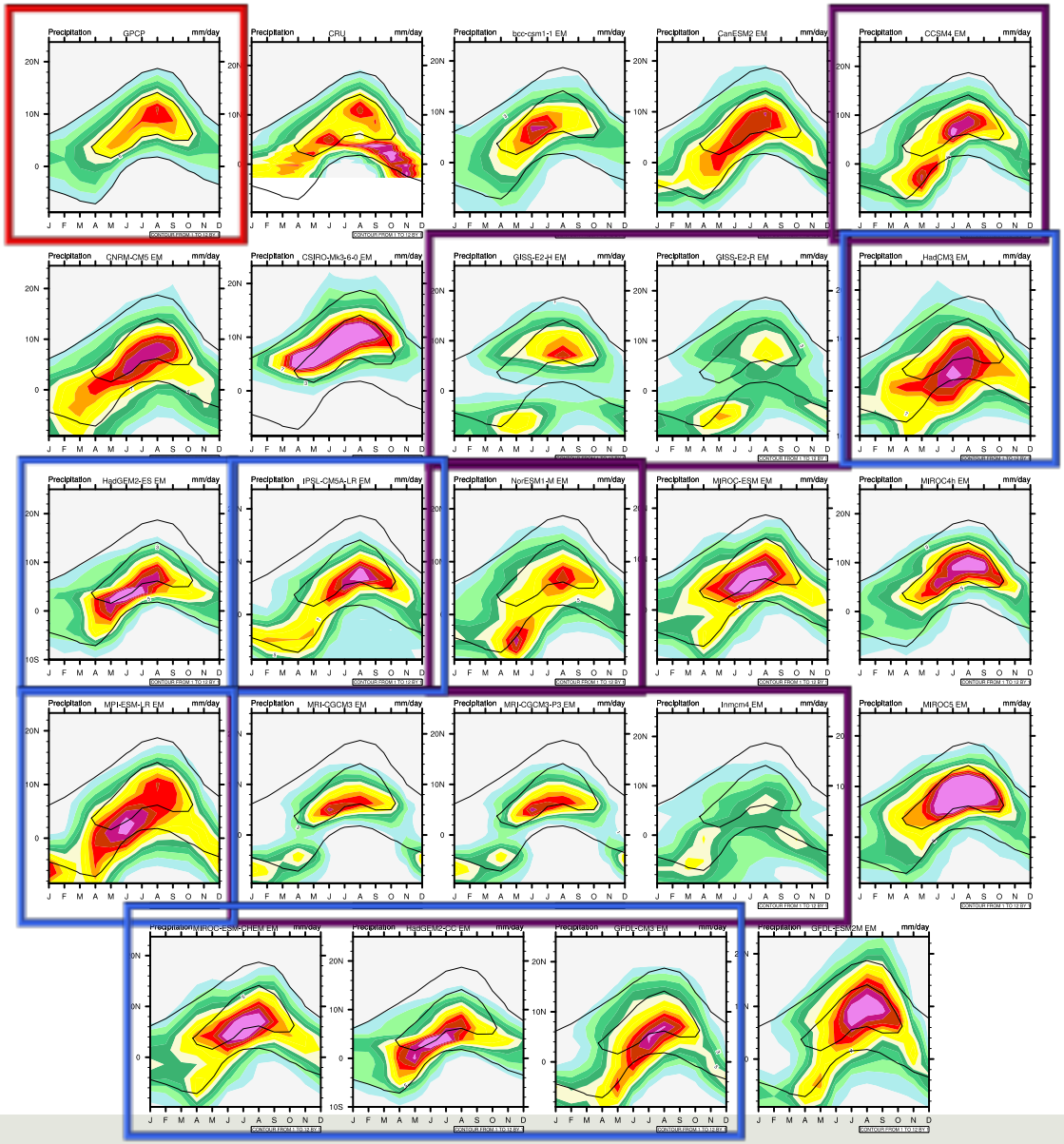
Vertical Wind Shear Regressed onto AMO Index





- Observed changes in wind shear with AMO phase
  - Reduced wind shear in warm AMO phases in MDR
- Good models similar pattern but weaker amplitude
- Poor models have little response to AMO variability

Precipitation Annual Cycle

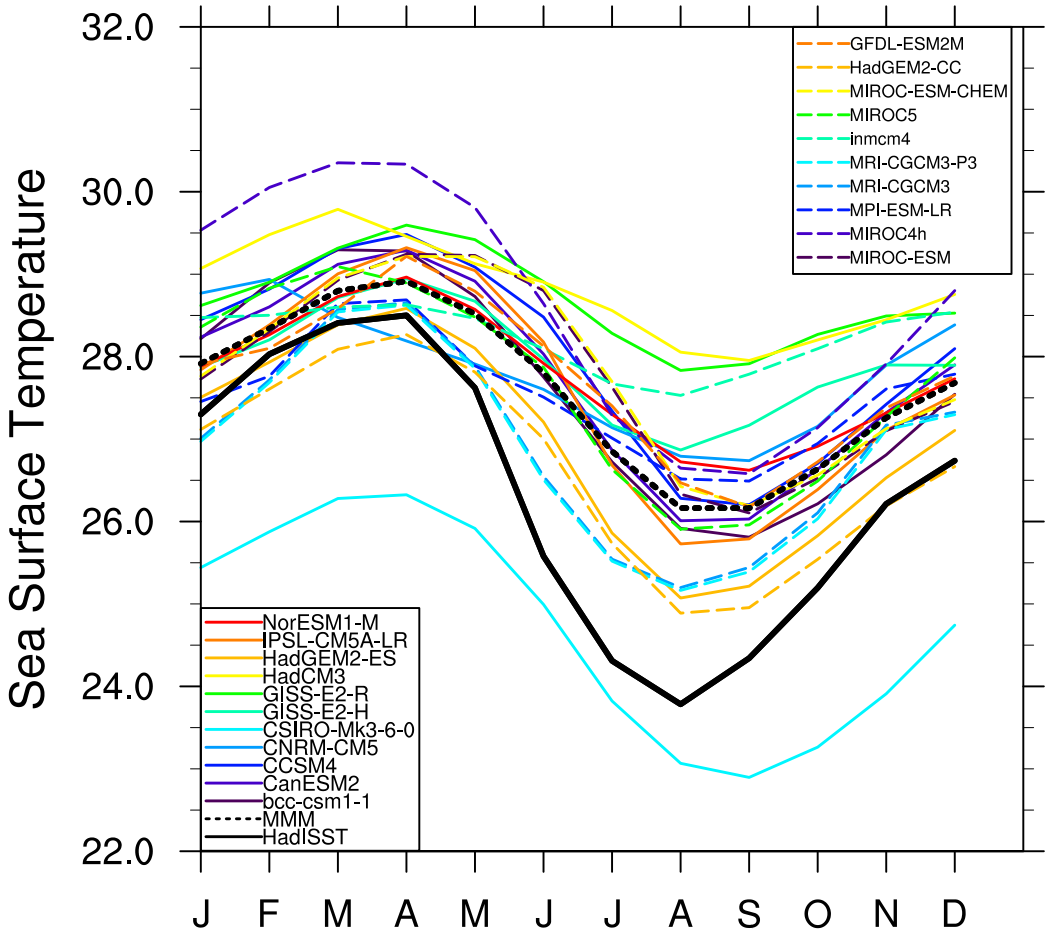


Observations

Discontinuity from Southern hemisphere to Sahel

Rainfall peak too far South

Gulf of Guinea SST Annual Cycle



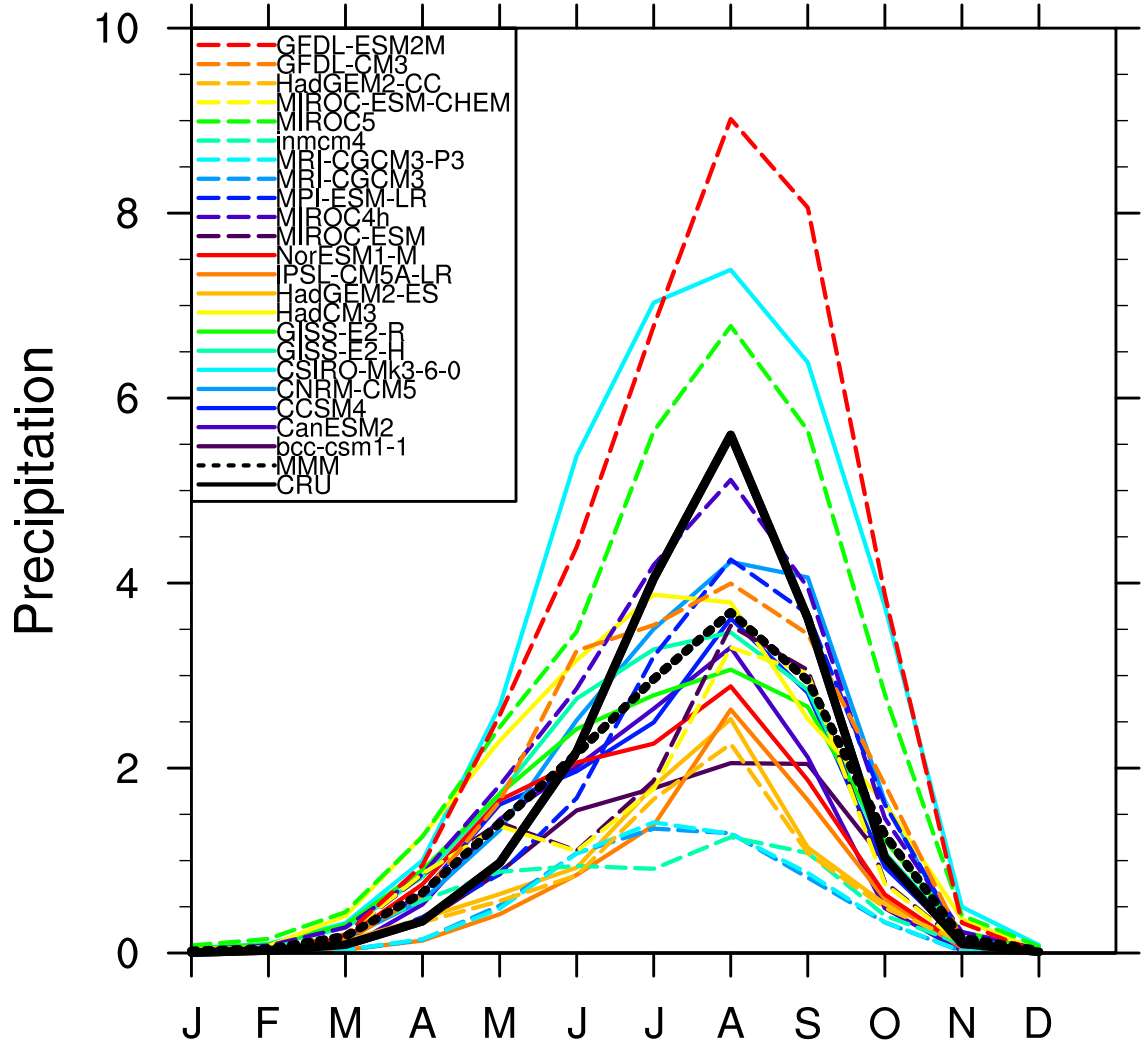
As in CMIP3 models: Warm anomaly in SE Atlantic and Gulf of Guinea in summer

Errors of up to 4°C

On interannual timescales:

warm Gulf of Guinea = dry Sahel

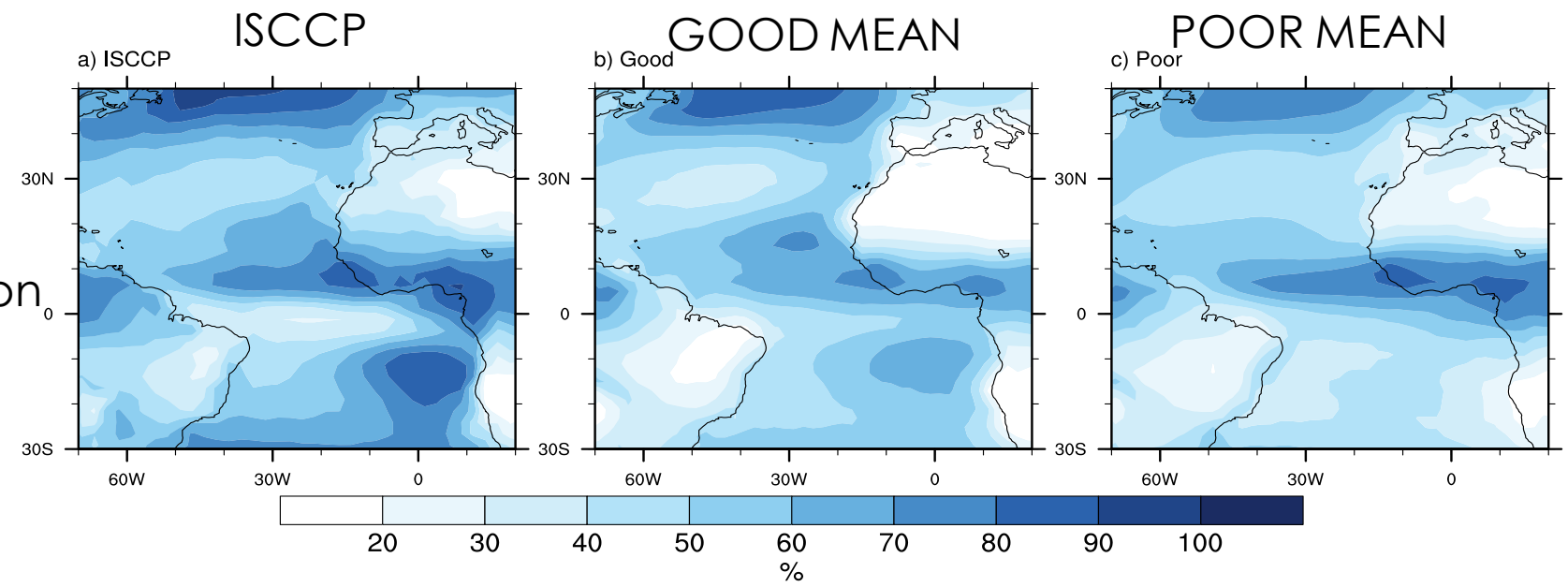
Sahel Rainfall Annual Cycle



- Summer monsoon peak is simulated but most models:
  - underestimate summer peak
  - overestimate spring rainfall

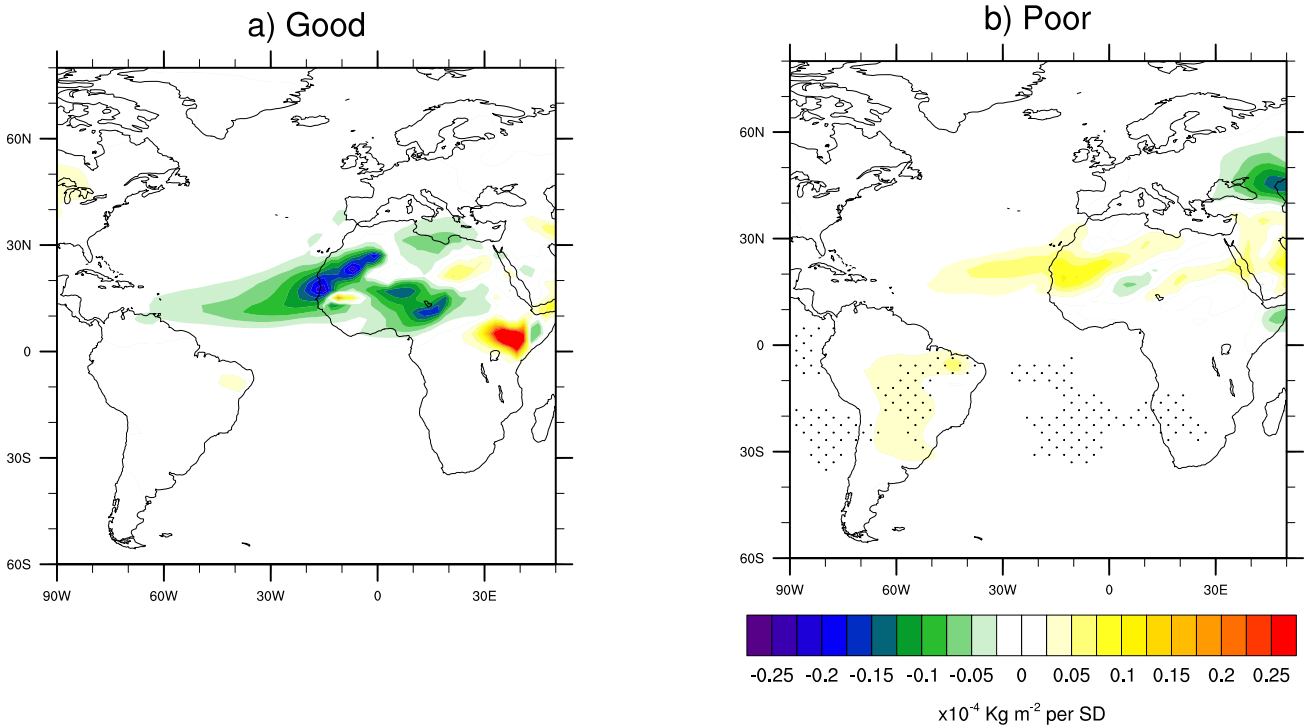
Role of Clouds

Total Cloud Fraction



- Larger (more realistic) total cloud amount and variability in eastern basin of good models
- Is total mean cloud amount related to simulation of SST variability?

Role of Dust

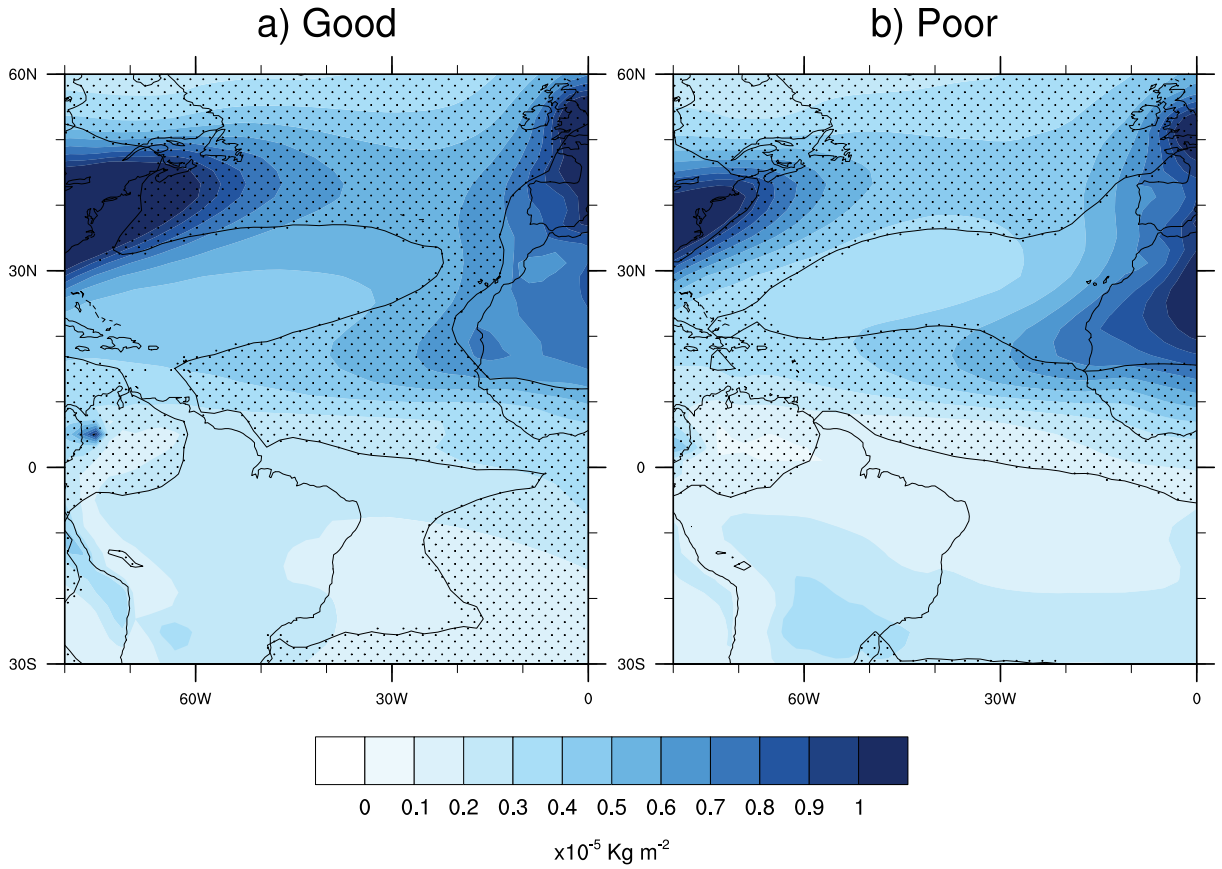


- Dust load regressed onto AMO index
- Good Models:
  - As expected increase SST, increase rain, reduce dust
- Opposite seen in poor models

Role of Sulfate Aerosol Indirect Effects

Shading: Mean sulfate aerosol load

Stippling: >50 % total cloud fraction



Need cloud and sulfate in same location for indirect effect to occur

✓ Good Models

✕ Poor Models